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Multi-spacecraft attitude cooperative control using model-based event-triggered methodology

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Abstract

The attitude cooperative control of multi-spacecraft under undirected information flow is studied in this paper based on a novel state-irrelevant event-triggered control (ETC) strategy. In the proposed algorithm, the control updating and data-transfer among spacecraft need only be executed when certain conditions are triggered. Then, the system model is utilized to predict the future state based on the last transmission and to calculate the time of the next transmission event. Firstly, the proposed algorithm reduces the control updating frequency remarkably and avoids continuous communication; secondly, each spacecraft updates its controller independently, without requiring all members to update simultaneously; thirdly, it is still effective in the presence of input limitation. The consensus can be guaranteed under such control strategy. It has proved that there exists a lower bound for the update interval, avoiding a phenomenon that the infinite number of events may appear in a finite time interval, also called the Zeno phenomenon. The efficacy of the proposed algorithm is verified via simulations.

***Key words*:** Attitude cooperative; Multi-spacecraft formation; Event-triggered control;

1. Introduction

Utilization of groups of small satellites is becoming increasingly popular because of the low cost involved in their development and launching (Kim et al., 2016). Compared with the traditional large spacecraft, the coordination of distributed spacecraft with smaller size and less-expensive costs can bring many benefits, including more flexibility, reliability, and higher robustness (Hu et al., 2015). Attitude control system, as one of the spacecraft's subsystems, plays an important role in spacecraft design (Yin et al., 2016). Lots of reliable fault-tolerant researches have been yielded (Hu and Shao, 2016), (Xiao et al., 2014), (Cao et al., 2013), (Zhang et al., 2018a). The attitude cooperative control of multi-spacecraft formation has been extensively studied and benefit various aerospace missions, for example, satellite surveillance, distributed aperture radar, extension planet detection optical interferometry, stereo-imaging platforms for space science (Li and Kumar, 2012), (Hu and Zhang, 2015) etc.. The relative attitude between spacecraft is required to be maintained precisely during formation manoeuvres (Wu et al., 2011).

Recently, researches on attitude cooperative control have been carried out, such as (Zhou et al., 2015a), (Hu et al., 2015), (Li and Kumar, 2012),(Yang et al., 2014), (Zhang et al., 2019), etc.. Nevertheless, they have one same problem in which the controller is needed to be updated continuously. Despite the rapid development of electronic technology, embedded resources on the spacecraft are still limited (energy, memory space, computing power, etc.) (Cai et al., 2008). Future spacecraft will be expected to achieve highly accurate pointing, fast slewing and low-cost energy in the practical environment (Lu and Xia, 2014). The limited capacities of communication and computation are constraints, in various scenarios, information is transmitted via wireless networks and the communication constraints affect the control performance (Fan et al., 2017) which cannot be ignored and have motivated the researchers to do the investigation of time-triggered control in information transmission. In (Wei et al., 2017) the authors indicate that within the time-triggered sampling framework, the sampled data is transmitted periodically, and the control tasks are also executed periodically. Through this intermittent data transmission approach, resource consumption is reduced. Such as, in (Zhu et al., 2017), the author used a prediction-based sampled-data control strategy to accomplish the attitude stabilization of a rigid spacecraft. And in (Sun et al., 2017) Sun et al. achieved fault-tolerant control based on the sampling method. Some related studies can be found in the literature (Dai et al., 2017). However, although the sampling approach greatly reduces the consumption of resources, lately, investigators have indicated that the time-triggered sampling approach may still give rise to redundant information transmission (Zhu et al., 2017). Such as, if there is a slight variation between the two successive sampled data, it is not necessary to transmit the information and update the controllers to a degree. Besides, continuous communication among neighbouring spacecraft is often used for distributed control scheme design. However, continuous communication is an ideal assumption, it is more realistic to interact intermittently at discrete sampling instants (Meng and Chen, 2013).

To avoid the drawbacks and inherit the advantages in the sampling control of reducing resource consumption, an ETC method is first proposed by Dimarogonas et al. (Dimos V. Dimarogonas et al., 2012). Since then, ETC approach has received a lot of attention, and numerous research results have been produced, (Seyboth et al., 2013), (Yang et al., 2016), (Wei et al., 2017) and therein. In the event-triggered mechanism, event-triggering conditions are aimed to decide whether the data deserve to be transmitted for control updating (Wei et al., 2017). In this way, many redundant, unnecessary updates to the controller which will occur in the sampling control method, will not happen in ETC approach, because they do not satisfy the conditions that could trigger the updating condition. Currently, there are results on ETC to spacecraft, such as, (Wu et al., 2018), (Zhang et al., 2018b). Theoretical results of ETC are numerous, nevertheless, there are relatively few studies related to spacecraft control, which is the primary motivation of this paper.

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